

4.4.4. Quality Control

It is essential for tidal datum quality control to have data processing and leveling procedures carried out to the fullest extent. Caution must also be used in computing tidal datums in riverine systems or in regions of unknown tidal regimes. Tide-by-tide comparisons between subordinate and control station data will often detect anomalous differences which should be investigated for possible gauge malfunction or sensor movement. Datums shall be established from more than one bench mark. Differences in elevations between bench marks based on new leveling must agree with previously established differences from the published bench mark sheets. Any changes in the elevation differences must be reconciled before using in any datum recovery procedure. Datum accuracy at a subordinate station depends on various factors, but availability and choice of an adequate control station of similar tidal characteristics, similar daily mean sea level and seasonal mean sea level variations, and similar sea level trends are the most important. The length of series will also determine accuracy. The longer the series, the more accurate the datum and the greater quality control and confidence gained from analyzing numerous monthly mean differences between the subordinate and control station. At reoccupied historical stations for which datum recoveries are made, updated datums shall be computed from the new time series and compared with the historical datums as the survey progresses.

4.4.5. Geodetic Datum Relationships

Tidal datums are local vertical datums which may change considerably within a geographical area. A geodetic datum, is a fixed plane of reference for vertical control of land elevations. The North American Vertical Datum of 1988 (NAVD 88) is the accepted geodetic reference datum of the National Geodetic Spatial Reference System and is officially supported by the National Geodetic Survey (NGS) through a network of GPS continuously operating reference stations. The relationship of tidal datums to NAVD has many hydrographic, coastal mapping and engineering applications including monitoring sea level change and the deployment of GPS electronic chart display and information systems. An orthometric level connection or ellipsoidal GPS tie is required at subordinate tide stations which have geodetic bench marks located within a radius of 0.25 miles. At least two geodetic bench marks should be used to complete the connection for quality control purposes. In addition, at stations with no geodetic bench marks located nearby, GPS ellipsoidal heights will be established for at least three of the bench marks in the local tide station network (see NOAA Technical Memorandum NOS NGS-58).

4.5. Final Zoning and Tide Reducers

Data relative to MLLW from subordinate stations or from NOS NWLON stations, as appropriate, shall be applied to reduce sounding data to chart datum, either directly or indirectly through a correction technique referred to as tidal zoning. Whether corrected or direct, time series data relative to MLLW or other applicable LWD applied to reference hydrographic soundings to chart datum are referred to as “tide reducers” or “water level reducers.”

4.5.1. Water Level Station Summaries

Data are reduced to mean values and subsequently adjusted to National Tidal Datum Epoch (NTDE) values for tidal datums and characteristic tidal attributes as prescribed in Section 4. and 5. “Summary files” will be created for each subordinate tide station occupied for the survey. These summary data facilitate the development of corange and cophase lines and final zoning schemes. They also provide input into the NOS tidal datum bench mark publication process which supports navigation, boundary and shoreline determination, coastal engineering and management. NTDE values for Greenwich high and low water intervals, mean and diurnal ranges, and high and low water inequalities shall be tabulated in these summary files which also contain the datums, the time and length of the series and NOS control station which was used to compute 19-year equivalent NTDE values. NTDE datums shall be tabulated in the summary file relative to a documented consistent station datum such as tide staff zero or arbitrary station datum. The elevation of the primary bench

mark shall be provided in this summary relative to the same zero or station datum. Latitude and longitude positions shall also be provided. An example of a summary file is provided in Figure 4.8.

Summary file data from new station occupations and NOS provided summaries from historical occupations and control stations within the survey area shall be used as input data to the tidal zoning process.

4.5.2. Construction of Final Tidal Zoning Schemes

As tidal characteristics vary spatially, data from deployed water level gauges may not be representative of water levels across a survey area. Tidal zoning shall be implemented to facilitate the provision of time series water level data relative to chart datum for any point within the survey area, such that prescribed accuracy requirements are maintained for the water level measurement component of the hydrographic survey. NOS currently utilizes the “discrete tidal zoning” method for operations, where survey areas are broken up into a scheme of cells bounding areas of common tidal characteristics. The minimum requirement is for a new cell for every 0.06 m change in mean range of tide and every 0.3 hour progression in time of tide (Greenwich high and low water intervals). Phase and amplitude corrections for appropriate tide station data shall be assigned to each cell.

As part of the process, tidal characteristics shall be accessed using geographic spacial placement of summary data in a commercial GIS compatible format to assess spatial variations in tidal characteristics. Corange and cophase maps shall be generated to provide the base for development of zoning schemes. Preliminary zoning, which is based on available historical tide station data and estuarine and global tide models, is referenced to an applicable predictions reference station for utilization during field work. For final processing, preliminary zoning shall be superseded by “final zoning” which is a refinement based on new data collected at subordinate stations during the survey. With the final zoning scheme, correctors for each zone shall be derived from a subordinate station specifically installed for the survey rather than the reference station used with preliminary zoning. For contract surveys, the contractor shall develop and utilize a zoning scheme to the specifications mentioned above such that water level reducers are within required accuracy across the entire survey area. Zoning errors shall be minimized such that when combined with errors from actual water level measurement at the gauge and errors in reduction to chart datum, the total error of the tide reducers is within specified tolerances. The final zoning scheme and all data utilized in its development shall be documented and submitted. Examples of zoning files and graphics are provided in Figures 4.9, 4.10, 4.11, 4.12, and 4.14.

4.5.3. Tide Reducer Files and Final Tide Note

Verified time series data collected at appropriate subordinate stations are referenced to the NTDE Mean Lower Low Water (Chart Datum) through datum computation procedures outlined in Section 4.4. Time series data collected in six-minute intervals and reduced to chart datum as specified, from both subordinate gauges operated by the contractor and from NOS NWLON stations where appropriate, shall be used either directly or corrected through use of a zoning scheme as determined appropriate by the contractor such that tide reducers are within specified tolerances. A Final Tide Note shall be submitted for each hydrographic sheet with information as to what final tidal zoning should be applied to which stations to obtain the final tide reducers. An example of a Final tide Note and final tidal zoning graphic is found in Figure 4.14.

4.6. Data Submission Requirements

Data submission requirements for water level measurement stations are comprised of both supporting documents for the installation, maintenance, and removal of stations, and the formatted digital water level data collected by the water level measurement system required for NOS quality control and ingestion into the NOS data base management system. In addition, documentation for processing and tabulation of the data, tidal datum computation, and final tidal zoning are required.

4.6.1. Station Documentation

The documentation package shall be forwarded to CO-OPS within 10 business days of: a) installation of a station, b) performance of bracketing levels, c) gauge maintenance and repair, or d) removal of the station. Refer to Section 4.2.6 for general documentation requirements and Figure 4.13, Water Level Station Documentation Checkoff List. The station documentation generally includes, but is not limited to the following:

- (a) Field Tide Note
- (b) Calibration test documentation from an independent source other than the manufacturer for each sensor used to collect water level or ancillary data.
- (c) NGWLMS Site Report (see *Next Generation Water level Measurement System Site Design, Preparation, and Installation Manual*), and/or Tide Station Report (NOAA Form 77-12), or Great Lakes Water Level Station Report (NOAA Form 77-75).
- (d) New or updated Nautical chart section or U.S. Geological Survey quadrangle map indicating the exact location of the station, with chart number or map name and scale shown.
- (e) Large-scale sketch of the station site or digital GIS compatible file provided on diskette showing the relative location of the water level gauge, staff (if any), bench marks, and major reference objects found in the bench mark descriptions. The sketch shall include an arrow indicating north direction, a title block, and latitude and longitude (derived from handheld GPS) of the gauge and all bench marks.
- (f) New or updated description of how to reach the station from a major geographical landmark.
- (g) Photographs of station components and bench marks. Digital photographs are preferred. As a minimum, photographs shall show a view of the water level measurement system as installed, including sensors and DCP; a front view of the staff (if any); multiple views of the surroundings and other views necessary to document the location; and photographs of each bench mark, including a location view and a close-up showing the bench mark stamping. All photographs shall be annotated and referenced with the station name, number, location, and date of the photograph.
- (h) Description/Recovery Notes of Bench Marks (see *User's Guide for Writing Bench Mark Descriptions*, NOAA/NOS, March 1998).
- (i) Level records and level abstract.
- (j) Datum offset computation worksheet or Staff/Gauge difference work sheet as appropriate showing how sensor "zero" is referenced to the bench marks.

Figure 4.13

WATER LEVEL STATION DOCUMENTATION CHECKOFF LIST

Project Number: _____ Locality: _____

Station Number: _____ Station Name: _____

A. Field Tide Note

- ____ 1. Verify latitude and longitude with handheld GPS.
- ____ 2. Verify dates.

B. Site Report (required for both installation and removal)

- ____ 1. All applicable information complete, especially serial numbers of DCP/sensors and dates of installation/removal of DCP/sensors and levels.
- ____ 2. Verify latitude and longitude (ensure that this is the same as on the field tide note).
- ____ 3. Denote latitude and longitude as NAD 83. Also note if position was derived from handheld GPS.

C. Chart Section

- ____ 1. Ensure that station location is clearly depicted with circle and station number.
- ____ 2. Note chart number, edition, date and scale.

D. Bench Mark/Station Location Sketch

- ____ 1. Gage/staff and bench marks shown.
- ____ 2. Title block provided (NOAA Form 76-199).
- ____ 3. North arrow depicted.
- ____ 4. Include hard copy sketch and GIS digital format on diskette.

E. Photographs

- ____ 1. Digital photographs of gage, staff and surrounding area (CD ROM or other appropriate media)

F. Bench Mark Descriptions/Recovery Notes

- ____ 1. Stampings for new and recovered marks verified.
- ____ 2. Descriptions for new marks provided in NOS format (WP 6.0).
- ____ 3. Recovery notes provided for all historical marks.

Figure 4.13 (cont.)

G. Levels (NOAA Form 76-77 or Form 75-29)

- ___ 1. Ensure all information written in ink.
- ___ 2. Cover information complete; station name, number, instrument and rod type, serial numbers, date, personnel.
- ___ 3. Note types of levels; installation, bracketing and closing.
- ___ 4. Staff information complete (if applicable).
- ___ 5. Collimation check shown.
- ___ 6. Note that bench mark descriptions are submitted on separate sheets.
- ___ 7. Headers on all applicable pages complete.
- ___ 8. Level run, abstract on page 30, and differences/elevations on page 31 verified and initialed.

H. Datum Offset Computation Worksheet

- ___ 1. Submit for stations using Vitel or Sutron 8200 DCP with Aquatrak sensor.

I. Data Submitted on Diskettes (or other digital media)

- ___ 1. Label diskettes with contractor name and list of files on each diskettes.
- ___ 2. Data files should be named in the following format: xxxxxxx1.dat, where x= station number and 1 is the DCP designation. For multiple files from the same station, change the extension, i.e., xxxxxxx1.da1, da2, etc.
- ___ 3. Check the begin and end dates of data submitted with dates of hydrographic operations.
- ___ 4. Check data continuity.

J. Transmittal Letter

- ___ 1. Transmittal letter attached with current contractor address, phone number and email.

K. All Documentation Enclosed in Tide Level Envelope (NOAA Form 75-29A)

- ___ 1. Leave "sheets" box blank, complete other information in title boxes.
- ___ 2. Verified complete by Contractor and Include date.

Figure 4.14**FINAL TIDE NOTE and FINAL TIDAL ZONING CHART**

DATE: December 22, 1999

HYDROGRAPHIC BRANCH: Pacific

HYDROGRAPHIC PROJECT: OPR-P342-RA-99

HYDROGRAPHIC SHEET: H-10910

LOCALITY: 6 NM Northwest of Cape Kasilof, AK

TIME PERIOD: July 22 - August 20, 1999

TIDE STATION USED: 945-5711 Cape Kasilof, AK

Lat. 60° 20.2'N Lon. 151° 22.8'W

PLANE OF REFERENCE (MEAN LOWER LOW WATER): 0.000 meters

HEIGHT OF HIGH WATER ABOVE PLANE OF REFERENCE: 5.850 meters

REMARKS: RECOMMENDED ZONING

Use zone(s) identified as: CK394, CK395, CK399, CK400, CK401, CK407, CK408, CK409, CK434, CK435, CK441, CK442, CK443, CK467, CK468, CK469, CK470, CK477, CK480, CK481, CK482, CK483, CK493 & CK494.

Refer to attachments for zoning information.

Note 1: Provided time series data are tabulated in metric units (Meters), relative to MLLW and on Greenwich Mean Time.

Note 2: Nikiski, AK served as datum control for subordinate tide stations and for tidal zoning in this hydrographic survey. Accepted datums for this station have been updated recently and have changed significantly from previous values.

The current National Tidal Datum Epoch (NTDE) used to compute tidal datums at tide stations is the 1960-78 NTDE. Traditionally, NTDEs have been adjusted when significant changes in mean sea level (MSL) trends were found through analyses amongst the National Water Level Observation Network (NWLON) stations. Epochs are updated to ensure that tidal datums are the most accurate and practical for navigation, surveying and engineering applications and reflect the existing local sea level conditions. For instance, analyses of sea level trends show that a new NTDE is necessary and efforts are underway to update the 1960-78 NTDE to a more recent 19-year time period.

4.6.2. Water Level Data

The final observed water level measurements shall be reported as heights in meters to three decimal places (i.e. 0.001 m). All heights shall be referenced to station datum and shall be referenced to UTC. The final tide reducer time series data shall be referenced to MLLW and shall be referenced to UTC.

The original raw water level data and also the correctors used to convert the data to chart datum shall be retained until notified in writing or at least two years after the survey is completed. All algorithms and conversions used to provide correctors shall be fully supported by the calibrations, maintenance documentation, leveling records, and sound engineering/oceanographic practices. Sensors for measurements used to convert data (e.g. pressure to heights) shall be calibrated and maintained for the entire water level collection period.

All digital water level and ancillary data shall be transmitted to CO-OPS in a format dependent on the DCP configuration. If GOES satellite is used, the data shall be transmitted and received using the NOS compressed pseudo binary format (see NGWLMS GOES Message Formatting, Libraro, 1998). These satellite messages are then decoded by NOS DPAS upon receipt from NESDIS before further processing and review by CORMS can be completed. If satellite transmission configurations cannot be installed, the data shall be manually downloaded from the DCP and submitted to NOS at least monthly, by the 10th of the month, in the format below on 3.5 inch floppy disk or by email as an ASCII data attachment. It may be prudent to submit data at more frequent intervals under specific circumstances. Data download files shall be named in the following format: xxxxxxxy.DAZ, where x is the seven digit station number, y is the DCP number (usually 1), and DAZ is the extension (where Z = 1,2,3...if more than one file is from the same station and DCP). This is the format needed when the data is loaded into DPAS.

The 6-minute interval data (acoustic sensor and pressure sensor examples follow) shall have the following format once decoded:

Acoustic Sensor Data

Column 1-7	Station ID (assigned in the project instructions)
Column 8	1 (DCP number, use 2, 3 , etc., for additional DCPs)
Column 9-19	Date (MMM DD YYYY format, e.g. JAN 01 1998)
Column 20	Blank
Column 21-22	Hours in 24 hour format (i.e. 01, 01, ..., 23)
Column 23	: (place a colon)
Column 24-25	Minutes (00,06,12,etc..)
Column 26-32	Data value in millimeters, right justified, (e.g. 1138)
Column 33-38	Sigma (standard deviation in millimeters in integer format)
Column 39-44	Outlier (integer format)
Column 45-50	Temperature 1 (tenth of degrees C in integer format)
Column 51-56	Temperature 2 (tenth of degrees C in integer format)
Column 57-58	Sensor type (A1 for acoustic type)
Column 59-60	blank
Column 61-61	Data Source (S for Satellite, D for Diskette)

Sample data:

```
85169901AUG 17 1993 05:00 1138 23 0 308 297A1 S
85169901AUG 17 1993 05:06 1126 26 0 308 298A1 S
85169901AUG 17 1993 05:12 1107 26 1 309 298A1 S
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Pressure Sensor Data

Column 1-7	Station ID (assigned in the project instructions)
Column 8	1 (DCP number, use 2, 3 , etc., for additional DCPs)
Column 9-19	Date (MMM DD YYYY format, e.g. JAN 01 1998)
Column 20	Blank
Column 21-22	Hours in 24 hour format (i.e. 01, 01, ..., 23)
Column 23	: (place a colon)
Column 24-25	Minutes (00-59)
Column 26-32	Data value in millimeters, right justified, (e.g. 1138)
Column 33-38	Sigma (standard deviation in millimeters in integer format)
Column 39-44	Outlier (integer format)
Column 45-50	DCP temperature (tenth of degrees C in integer format)
Column 51-52	Sensor type (B1 for pressure type)
Column 53-53	blank
Column 54-54	Data Source (S for Satellite, D for Diskette)

```
85169901AUG 17 1993 05:00  1138  23  0 308B1 S
85169901AUG 17 1993 05:06  1126  26  0 308B1 S
85169901AUG 17 1993 05:12  1107  26  1 309B1 S
```

Note: pressure data must be accompanied by documented daily staff readings.

4.6.3. Tabulations and Tidal Datums

For contract surveys, the contract hydrographer shall provide digital and hard copies of tabulations of staff/gauge differences, hourly heights, high and low waters, and monthly means for the entire time series of observations from each station. Along with the final contractor computed tidal datums, the contractor shall provide copies of the tide-by-tide and/or monthly mean simultaneous comparison sheets from which the final tidal datums were determined. Audit trails of data edits and gap-filling shall be summarized and provided also.

The digital tabulation files for hourly heights and high and low waters shall have the following formats:

Hourly height data

COLUMN

1 - 7	Station ID number
8 - 11	Year
12 - 13	Month
14 - 15	Day
16	Line Number (1 = 1st line of day for 0 to 11 hours, 2 = 2nd line of day for 12 to 23 hours).
17 - 20	Time Meridian (Example: 000W)
21 - 26	0/12 Hourly height in meters (to millimeter resolution)
27 - 32	1/13 Hourly height in meters (to millimeter resolution)
31 - 38	2/14 Hourly height in meters (to millimeter resolution)
39 - 44	3/15 Hourly height in meters (to millimeter resolution)
45 - 50	4/16 Hourly height in meters (to millimeter resolution)
51 - 56	5/17 Hourly height in meters (to millimeter resolution)
57 - 62	6/18 Hourly height in meters (to millimeter resolution)
63 - 68	7/19 Hourly height in meters (to millimeter resolution)
69 - 74	8/20 Hourly height in meters (to millimeter resolution)

75 - 80	9/21	Hourly height in meters (to millimeter resolution)
81 - 86	10/22	Hourly height in meters (to millimeter resolution)
87 - 92	11/23	Hourly height in meters (to millimeter resolution)

High and Low Water data

COLUMN

1 - 7	Station ID Number
8 - 9	Year
10 - 11	Month
12 - 13	Day
14 - 17	Time Meridian (Example: 075W)
18 - 26	First Tide
18	1 = High
	2 = Low
	3 = Higher High
	4 = Lower Low
19	0 Nothing unusual/Normal
	1 If Inferred Tide
	2 If Flat Tide
	3 If Extra Tide
	4 If Inferred and Flat Tide
	5 If Extra and Flat Tide
20 - 22	Hour (Tenths of Hours)
23 - 27	Height (in meters to millimeter resolution)
28 - 37	Second Tide
38 - 47	Third Tide
48 - 57	Fourth Tide
58 - 67	Fifth Tide (If any)
68 - 77	Sixth Tide (If any)
78 - 87	Seventh Tide (If any)

4.6.4. Tide Reducers and Final Zoning and Final Tide Note

The final zoning scheme shall be fully supported by documentation of data and methodology which comprised the final zoning model. Final tide reducers shall be submitted in the specified format.

All documentation listed below shall be forwarded to CO-OPS:

- (a) Contractor created summary files.
- (b) Documentation of NOS summary files utilized for final zoning
- (c) GIS compatible zoning development steps including geographical presentation of summary data and cophase/corange maps
- (d) GIS compatible digital final zoning files
- (e) Final tide reducer data files
- (f) Final Tide Note

The final zoning scheme shall be fully supported by documentation of data and methodology which comprised the final zoning model.

4.6.5. Submission

The check list in Figure 4.13 shall be used to check and verify the documentation that is required for submission.. All documentation, water level data, and reports shall be forwarded to the following address:

NOAA, National Ocean Service
Thomas Mero
Chief, Requirements and Development Division
N/OPS1, SSMC4, Station 6531
1305 East-West Highway
Silver Spring, MD 20910

Voice: 301-713-2897 ext. 145

Fax: 301 - 713-4436

4.7. Guidelines and References

References for the water level measurement and leveling requirements issued by the NOS Center of Operational Oceanographic Products and Services (CO-OPS) and the National Geodetic Survey (NGS) are listed below.

1. Next Generation Water Level Measurement System (NGWLMS) Site Design, Preparation, and Installation Manual, NOAA/NOS, January 1991.
2. User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, NOAA/NOS, dated October 1987.
3. User's Guide for Writing Bench Marks Descriptions, NOAA/NOS, February 1999.
4. User's Guide for Electronic Levels, NOAA/NOS, Draft February 1999.
5. User's Guide for 8200 Bubbler Gauges, NOAA/NOS, updated February 1998.
6. User's Guide for 8200 Acoustic Gauges, NOAA/NOS, updated August 1998.
7. Manual of Tide Observations, U.S. Department of Commerce, Publication 30-1, May 1965.
8. Tidal Datum Planes, U.S. Department of Commerce, Special Publication No.135, Marmer 1951.
9. Tide and Current Glossary, U.S. Department of Commerce, NOAA, NOS, October 1989. Standing Project Instructions: Great Lakes Water Levels, February 1978.
10. NOAA Technical Report NOS 64 "Variability of Tidal Datums and Accuracy in Determining Datums from Short Series of Observations", Swanson, 1974.
11. Tidal Datums and Their Applications, NOAA Technical Report NOS CO-OPS 1, U.S. Department of Commerce, NOAA, NOS, DRAFT December 1998.
12. Data Quality Assurance Guidelines for Marine Environmental Programs, Robert J. Farland, Office of Ocean Engineering, NOAA, March, 1980.

13. System Development Plan, CORMS: Continuous Operational Real-Time Monitoring System, NOAA Technical Report NOS OES 014, U.S. Department of Commerce, NOAA, NOS February, 1997.
14. NGWLMS GOES MESSAGE FORMATTING, Phil Libraro, 6/98.
15. Computational Techniques for Tidal Datums, NOAA Technical Report NOS CO-OPS 2, U.S. Department of Commerce, NOAA, NOS, DRAFT December 1998.
17. Standards and Specifications for Geodetic Control Networks, Federal Geodetic Control Committee, September 1984.
18. Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2CM and 5CM) Version 4.3, NOAA Technical Memorandum NOS NGS-58, November 1997.
19. Geodetic Leveling, NOAA Manual NOS NGS 3, U.S. Department of Commerce, NOAA, National Ocean Survey, August, 1981.